Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2008		**00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE
High Yield Magnetic Nanoparticles Filled Multiwalled Carbon Nanotubes Using Pulsed Laser Deposition

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Morgan State University,Department of Physics,Baltimore,MD,21251

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002137. Proceedings of the 2008 IEEE International Conference on Nanotechnology (8th) Held in Arlington, TX on August 18-21, 2008. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**2**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

High Yield Magnetic Nanoparticles Filled Multiwalled Carbon Nanotubes Using Pulsed Laser Deposition.

Dereje Seifu and Shashi P. Karna, *Senior Member IEEE*

Abstract— We present a high yield filling technique of multi-walled carbon nanotubes (MWNTs), grown vertically on a SiO_2 substrate, with magnetic nanoparticles using pulsed laser deposition (PLD). Magnetization measurements in-plane and out-of-plane with respect to the sample surface indicate reasonable coercivity estimated at 0.4 T. The magnetic anisotropy is however found to be randomly oriented, indicating a polycrystalline structure. The unique difference between the in-plane and out-of-plane magnetizations is the sharing produced by the demagnetizing field in the perpendicular direction.

BACKGROUND

Since its discovery in the early 1990s [1], there has been exponential increase in research on carbon nanotubes (CNTs) due to its potential for applications in a wide range of technologies. Of particular interest has been to realize CNTs impregnated with functional materials, such as the magnetic nanoparticles, which are of interest in electronics and data storage. A major technical challenge toward that has been the the assembly of ordered nanoscale structure and controlled filling. In recent years, there has been success in preparing vertically aligned nanotubes on SiO_2 substrate by chemical vapor deposition (CVD)[2]. In this paper, we report a single step procedure to fill vertically aligned multiwalled carbon nanotubes (MWNTs) with cobalt-ferrite using pulsed laser deposition (PLD).

There has been a previous attempt to fill MWNTs in aqueous suspension with cobalt ferrite [3]. Recently, we reported successful chemical filling of CNTs with ferrite nanoparticles [4]. The present work is the first attempt ever to fill MWNTs using PLD, a technique which is commonly used to prepare magnetic thin films. The method presented here offers technologically useful, aligned MWNTs, which are suitable for functional devices.

The author Dereje Seifu is with Morgan State University, Department of Physics, Baltimore, MD 21251: contact e-mail: Dereje.Seifu@morgan.edu.

The author Shashi P. Karna is with US Army Research Laboratory, Weapons and Materials Research Directorate, Aberdeen Proving Ground, Maryland, 21005-5069 USA.

Acknowledgment: We thank Drs. Sarah Lastella and P. M. Ajayan for providing us with vertically grown carbon nanotube samples. This work was supported by a grant from the Army Research Laboratory through the contract no. W 1813LT-5006-7056.

EXPERIMENT

Vertically aligned MWNTs were grown by CVD technique on SiO_2 substrate following the procedure of Wei et al [2]. This method involves exposing silica structures to a mixture of ferrocene and xylene at 770 ^{o}C for 10 min. The furnace is pumped down to ~200 mtorr in argon bleed and then heated to the temperature of 770 ^{o}C. The solution of ferrocene dissolved in xylene (~0.01g/ml) is pre-heated in a bubbler to 175 ^{o}C and then passed through the tube furnace. The furnace is then cooled down to room temperature.

The filling material $CoFe_2O_4$ has a great technological interest because of its large anisotropy and magnetostriction. The filling was carried out in high vacuum (2×10^{-7} Torr) where the polycrystalline $CoFe_2O_4$ was ablated with a pulsed excimer laser (KrF) at 1.5 J/cm^2 and 3Hz as energy density and repetition rate respectively. During deposition the SiO_2 template was heated at 300^{o}C and the target was rotated in order to ensure its uniform wear. A total of 12,000 shots were fired to fill the nano-tube structure.

RESULTS

Scanning electron microscope (SEM) image of the vertically aligned MWNTs grown on SiO_2 substrate before deposition is shown in Fig. 1. As shown in the figure, although the majority of the tubes are aligned vertically, a few are misaligned.

In Fig. 2, SEM of vertical tubes after being filled with cobalt ferrite is shown. The filling depth of the magnetic material in the vertically aligned tubes is not apparent from the SEM image. However, it is possible to obtain this information from the in-plane and out-of-plane magnetization measurements on the sample.

Magnetization measurements were performed with vibrating sample magnetometer, both in-plane and out-of-plane with respect to the sample surface. The result of the magnetization measurements are shown in Fig. 3, depicting the magnetic moment as a function of applied field. The hysteresis loop with solid line correspond to the in-plane and that with scatter points correspond to the out-of-plane magnetization. As is clear from Fig. 3 both loops indicate reasonable coercivity estimated at 0.4 T. However, the magnetic anisotropy appears to be randomly oriented (polycrystalline) since both loops exhibit the same hysteresis. The unique difference between the in-plane and out-of-plane magnetizations is the sharing produced by the demagnetizing field in the perpendicular direction.

SUMMARY

In summary, we have, for the first time, used pulsed laser deposition technique for high-yield magnetic nanoparticles filling of vertically aligned carbon nanotubes. The magnetization measurements suggest polycrystallinity of the filled magnetic nanoparticles, as evidenced from the randomly oriented magnetic anisotropy. We believe that our present work further extends the applications of CNT-based materials in electronics technologies.

REFERENCES

[1] S. Iijima, Nature, **354**, 56 (1991).

[2] B. Q. Wei, R. Vajtai, Y. Jung, J. Ward, R. Zhang, G. Ramanath, and P. M. Ajayan, Chem. Mater., **15**, 1598, (2003).

[3] N. Keller, C. Pham-Huu, C. Estournes, J. Greneche, G. Ehret, and M. Ledoux, Carbon, **42**, 1395, (2004).

[4] D. Seifu, Y. Hijji, G. Hirsch, and S. P. Karna, J. Magnet. Magn. Mat. **320**, 312 (2008)

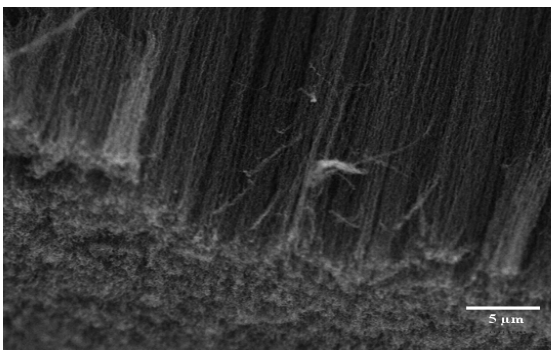

Figure 1: SEM micrograph of vertically grown MWNTs on SiO_2 before filling.

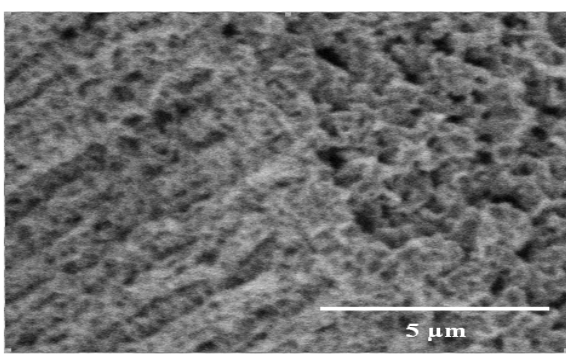

Figure 2 : Top view SEM image of vertically grown MWNTs on SiO_2 filled with $CoFe_2O_4$ by PLD at high resolution in (a) and in lower resolution (b).

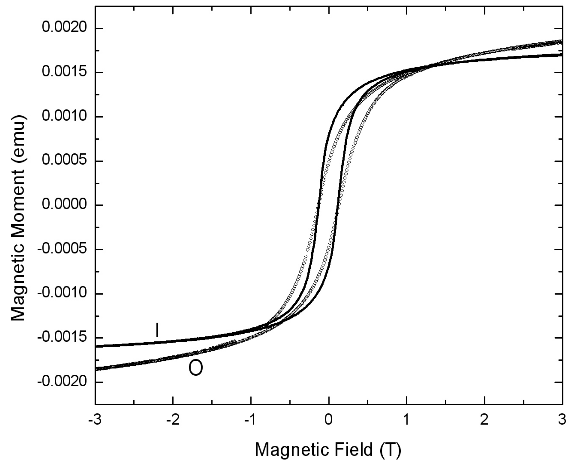

Figure 3: Magnetization of the cobalt ferrite nanoparticles filled, vertically aligned MWNTs. The solid lines represent in-plane and scatter plots represent out-of -plane magnetization.